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ORIGINAL ARTICLE

Soft tissue distraction in hand surgery: the "pentagonal frame" technique

Shahram Nazerani · Mohammad Hosein Kalantar Motamedi

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Abstract Soft tissue distraction (STD) is an increasingly accepted operation in all fields of hand surgery from elbow contracture release to PIP joint release. Current techniques reported lack the ability to distract the joints of the fingers or the hand, maintain the length of released contractures, and hold them in a position while active and passive physiotherapy is possible. We describe a technique by which STD of the hand and fingers is done with no joint or tendon involvement overcoming the aforementioned drawbacks. Thirty-three patients with hand contractures were treated. In this method, a thin 1–1.5-mm Kirschner wire was passed horizontally at the proximal head of the distal phalanx and bent like a frame around the finger, forming a pentagonal shape for anchorage. The distal distraction was exerted at the distal phalanx. Various forms of external fixation were then used to distract a finger, several fingers, or the hand by placing tension on this frame; the distraction was either static (with a wire exerting pressure) or dynamic (using a rubber band to adjust the tension). After obtaining the desired result, the wire or rubber band was temporarily freed to commence active and passive physiotherapy. We maintained the frame for 3–6 weeks. All 33 patients were successfully treated. No major complications were encountered during the follow-up period (3–5 years). The pentagonal frame allows for effective distraction of soft tissues and joint ligaments and maintains the space needed for healing of fractures of the metacarpals and phalanges.

Keywords Soft tissue distraction · Hand surgery

S. Nazerani
Department of Surgery, Iran University of Medical Sciences, Tehran, Islamic Republic of Iran

M. H. K. Motamedi
Trauma Research Center, Baqiyatallah Medical Sciences University, Tehran, Islamic Republic of Iran

M. H. K. Motamedi (✉)
Africa Expressway, Golestan St., Giti Blvd. No. 16, 19667 Tehran, Islamic Republic of Iran
e-mail: motamedical@lycos.com

Introduction

Application of distraction techniques to soft tissue contractures has been shown to be effective with minimal surgical tissue disruption [1, 2]. Soft tissue distraction for the management of radial club hand before the operation is becoming a standard in this category of patients [2]. During the past 5 years, we have used the pentagonal frame to treat 33 patients with contractures, trauma, and even congenital anomalies of the hand. A search in the literature revealed no previous report of this technique. In this paper, we present our results using this device.

Materials and methods

Between 2002 and 2007, we performed soft tissue distraction on 33 patients aged 6 months to 51 years with a variety of hand disorders leading to contracture. This included congenital deformities, burns, and contractures following trauma (Fig. 1).

Technique

In this method, after appropriate access (multiple Z or zigzag incisions for lengthening), the contracture was

Fig. 1 A fracture of the proximal phalanx of the little finger following trauma causing ankylosis due to a volar plate contracture

Fig. 2 The volar plate contracture released through a volar zigzag incision

Fig. 3 The pentagonal frame assembled and the finger put under tension

released (Fig. 2). A Kirschner wire size 1–1.5 mm (matching the patient's distal phalanx thickness) was used for anchorage. The wire was passed horizontally, under direct fluoroscopic control, through the head of the phalanx and then bent like a pentagon. Before closing the wire ends, a rubber band or wire was inserted inside the frame (Fig. 3). The frame is shaped such that only the horizontal wire segment exerts the "distraction," and no vascular compromise or soft tissue encroachment is created. An

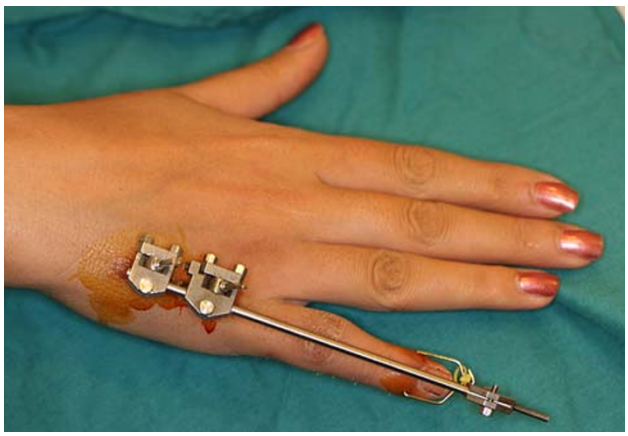

Fig. 4 External fixation device used for distraction

Fig. 5 Nearly full ROM after 4 weeks

Fig. 6 Complete extension

external fixation device was then used to distract a finger, several fingers, or the entire hand (Fig. 4). After achieving the desired distraction following joint contracture release, the finger or hand was temporarily freed, and active and passive physiotherapy was started while maintaining the frame; the fingers were put back into distraction after exercise to maintain the acquired length, especially with a

splint at night. The patient usually develops nearly a full range of motion (ROM) after 4 weeks (Fig. 5). The maximum result (complete flexion and extension) achieved at the end of distraction (Fig. 6) was maintained by using splints at night for up to 6 months. This prevented recurrence of contractures.

Results

There were 33 patients (23 males and 10 females) aged 6 months to 51 years (average 21.0 years). The patients underwent one to nine operations (average 3.0). The left hand was involved in 12 patients, and the right hand was involved in 17 patients. Four cases of bilateral injury were also treated. The etiology of contracture was congenital in 4 cases, industrial injuries in 15 cases, traffic accidents in 3 cases, and civilian injuries in 11 cases (Table 1). After the postoperative period when the frame was removed and the patient was discharged, the patients were followed periodically from 6 months to 5 years. The PIP joint contracture ranged from 110° to 50° of flexion contracture with a mean of 65°. The residual contracture ranged from 15° to 5° with a mean of 7° at the PIP joint level after 1 year of follow-up. The other joints had approximately the same results with a mean of 7° residual contracture. In four patients because of pin tract infection, we had to remove the frame. Usually 4 or 5 days were enough for the infection to resolve. During this time we removed the pin, and either the antibiotic dosage was increased or a combination of antibiotic regimens begun. To prevent contracture return during this interval, we continued the distraction by gluing a small hook to the nail and using a rubber band for loose but continuous distraction. No cases were resistant to distraction, and no cases of wire cutting through the bone following distraction were encountered. The only complications observed were pin-tract infection and soft tissue encroachment, which was relieved by proper antibiotics or realignment of the frame. No early or late complications concerning the distal phalanx or nail deformity of the distracted fingers were observed during the follow-up period from 3 to 5 years.

Discussion

Distraction is being used in all fields from maxillofacial to limb surgery [3–7]. Soft tissue distraction is becoming an increasingly accepted operation in all fields of hand surgery from elbow contracture release to PIP joint release, not only burn contracture release (which has been extensively reported by Joshi et al. or Suzuki) [8–10]. The idea of soft tissue distraction is not new, but the use of the distal phalanx as a distraction point and the pentagonal frame is a new addition to this field. Due to minimal complications and noninvolvement of tendinous structures, this frame can be used in all patients, be it joint contracture or epidermolysis bullosa. Active ROM exercise can begin as soon as possible without removing the frame. In the JESS system (by Dr. Joshi), you remove the frame and begin the exercises. The second advantage of distal phalanx distraction is that it can be used for lengthening the fingers and metacarpals, which we shall present in another article. The techniques reported lack the ability to distract the joints of the fingers or the hand, maintain the released contractures, and hold them in a position constantly without active and passive physiotherapy. The pentagonal frame reported in this paper was used to distract the soft tissues and joints of the hand and fingers. This was done by exerting distraction on a bone without involving tendons and joints with a concomitant physiotherapy regimen made possible. For PIP joint ankylosis due to volar plate contracture, after a healed phalangeal fracture, the volar plate is released through a volar zigzag incision, then the pentagonal frame is assembled and the finger is put under tension. Two to 3 days after surgery, physiotherapy can begin by releasing the rubber band and beginning active and passive exercises. The patient attains nearly a full range of motion (ROM) after 4 weeks. This device can also be used in congenital deformities (Fig. 7). Through volar zigzag incisions, the volar plates are released, and then the frame can be assembled and a plaster cast used to hold the fingers in extension. Two weeks after healing of the wounds, the fingers are in complete extension (Fig. 8). Severe volar contractures of fingers due to burns were also treated (Fig. 9). In such cases, after releasing the contractures, skin grafting, and assembling the frame, slow distraction can be started and continued until complete finger extension is obtained. During the first 4 weeks, only distraction is applied (Fig. 10). The frame may be removed after 6–8 weeks.

After complete healing of the grafts, physiotherapy may be added during the next 2 weeks to increase the range of motion. After a year, the ROM of fingers is near normal and without recurrence of contractures (Figs. 11, 12). By adding a rubber component to the frame, a dynamic traction is introduced into the device, which slowly but persistently distracts the soft tissues without incidence of vascular complication to date. The pentagonal frame allows for constant traction without involvement of tendons and joints and is a useful adjunct in soft tissue distraction for contractures of the hand. Due to the lack of any serious complications, this technique is being utilized as the first line of treatment for any contracture, but especially for contracted joints, such as volar plate release or in children in whom caring for a contracture is extremely

Table 1 Characteristics and demographic data of 33 patients treated for contractures via soft tissue distraction

No.	Diagnosis and type of contracture	Sex	Age	Extremity involved	Type of injury	Complications
1.	Bilateral upper extremity burn contracture, right little finger + wrist, left hand + wrist + forearm contracture	Female	20	R + L	Civilian	
2.	Right hand burn scar contracture long finger + little finger, extension contracture	Female	26	Right	Civilian	
3.	Severe left upper extremity flexion contracture elbow + axillary + hand extension burn contracture + ankylosis	Male	39	Left	Civilian	
4.	Right ring finger severe flexion contracture, long finger contracture	Male	18	Right	Industrial	
5.	Right long finger high pressure injection injury	Male	38	Right	Industrial	
6.	Left index electrical low voltage injury, soft tissue and bone destruction, pip joint	Male	2	Left	Civilian	Severe postop. eczema
7.	Right little finger flexion contracture skin and volar plate	Female	23	Right	Industrial	
8.	Right upper extremity ulnar, forearm and hand abrasion injury	Female	13	Right	Traffic accident	
9.	Left crushed hand, multiple fracture all fingers except little finger	Male	19	Left	Industrial	
10.	Left crushed hand, devascularized index and long fingers through zone 2, all other finger vascularized but crushed	Male	17	Left	Industrial	Index nonunion
11.	Right long- ring fingers flexion contracture PIP joint	Male	2	Right	Congenital	
12.	Left index zone 2A amputation incomplete several deep lacerations	Male	22	Left	Industrial	
13.	Left hand crushed injury from midpalm to distal fingers	Male	17	Left	Industrial	Necrosis long + ring finger
14.	Left hand crushed injury, devascularized thumb and index	Male	27	Left	Industrial	
15.	Crushed hand left metacarpal fracture and carpometacarpal dislocation	Male	26	Left	Industrial	
16.	Bilateral upper and lower extremity symbrachydactyly and growth arrest	Female	6 months	R + L	Congenital	Extruded schanzes
17.	Right hand syndactyly	Male	8 months	Right	Congenital	
18.	Epidermolysis bullosa upper and lower extremities severe contracture	Male	2	R + L	Congenital	
19.	Flexion contracture of PIP joint ring and little fingers right side	Male	50	Right	Civilian	
20.	Left ring PIP joint ankylosis	Male	51	Left	Civilian	
21.	Right index middle phalanx nonunion and flexion contracture	Male	19	Right	Industrial	
22.	Crushed devascularized left hand	Male	30	Left	Industrial	Nonunion proximal phalanges
23.	Right hand severe flexion contracture of all fingers	Male	21	Right	Civilian	
24.	Crush injury to dorsal right hand, volar elements of palm transected	Female	18	Right	Traffic accident	
25.	Explosion injury to the volar aspect of the left hand index and long fingers	Male	45	Left	Industrial	
26.	Crushed and dorsal right hand avulsion and all the extensors avulsed	Male	24	Right	Traffic accident	

Table 1 continued

No.	Diagnosis and type of contracture	Sex	Age	Extremity involved	Type of injury	Complications
27.	Right little finger transection and ulnar digital nerve compression	Female	21	Right	Civilian	Flexor adhesion
28.	Left hand crush injury from wrist to fingers	Male	22	Left	Industrial	Necrosis of long, ring and little fingers zone 1
29.	Amputation incomplete devascularized midpalm level, index, long, ring fingers, right hand	Male	16	Right	Industrial	
30.	Amputation zone 2, right hand index, ring, little finger malalignment	Female	22	Right	Civilian	Partial flap necrosis
31.	Flexion contracture + severe palmar right side	Male	20	Right	Civilian	
32.	Syndactyly right long + ring fingers Volkman's contracture, flexion contracture	Female	12	Right	Iatrogenic	Premature bony union
33.	Burn contracture dorsal hand bilateral	Female	7	R + L	Civilian	

Fig. 7 A 6-month-old infant with congenital joint contractures of the fingers of the left hand

Fig. 8 A plaster cast used to hold the fingers in extension. The result 2 weeks after operation

difficult by conventional means. The maximum achieved result at the end of distraction can only be maintained by night splints up to 6 months after the operation, after which

Fig. 9 Severe volar contracture of all four fingers following burns

Fig. 10 After releasing the contractures, skin grafting and assembling the frame, slow distraction was started and continued until complete finger extension was obtained. During the first 4 weeks, only distraction was applied

Fig. 11 One year after the operation the ROM of fingers is near normal, and there is no return of contractures

Fig. 12 Complete flexion

Fig. 13 A case of severe epidermolysis bullosa with severe flexion contracture and syndactyly of the fingers

Fig. 14 After releasing the contractures and putting the pentagonal frames in place, no attempt is made to separate the fingers since they were glued together by coagulum only

Fig. 15 The result after 6 months shows satisfactory extension

Fig. 16 Satisfactory flexion

it will not recur. Thus, careful follow-up is of utmost importance to keep the residual contracture as low as possible. The other indication for using this method is in

epidermolysis bullosa patients in whom it is impossible to use a splint due to very sensitive skin. We treated a severe case of epidermolysis bullosa with severe flexion contracture and syndactyly of the fingers (Fig. 13). After releasing the contractures and putting the pentagonal frames in place, no attempt was made to separate the fingers since they were glued together by coagulum only (Fig. 14). The result after 6 months showed satisfactory extension and flexion (Figs. 15, 16).

This technique differs from other methods in that it does not involve the tendinous structures like other devices do (i.e., Agee Digit Widget). As noted in this marketed device, the distraction force is in line with the schanzes inserted into the bone piercing the middle phalanx extensor tendon; it has the propensity to be pulled out if the force is increased. In our method, the distraction force is perpendicular to the pin inserted, and also because of its pentagonal design, it will exert pressure only on the bone; no soft tissue structure is involved in distraction. Thus, it can at first be used as a distraction device to slowly distract the soft tissues, and then after reaching the best possible result, active and passive physiotherapy can begin. There has been no mention of using the distal phalanx to achieve phalangeal, metacarpal, or soft tissue distraction in the literature.

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